PROGRESS REPORT

August 16, 1948

to

OFFICE OF NAVAL RESEARCH
NAVY DEPARTMENT
CONTRACT NO. N5-ori-111,
PROJECT ORDER NO. 1

on

Fundamental Studies of
Ceramic Materials

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BATTELLE
MEMORIAL INSTITUTE
505 King Avenue
COLUMBUS 1, OHIO

FORM 49

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COLUMBUS 1, OHIO

September 9, 1948

Chief of Naval Research
Navy Department
Washington 25, D. C.

Attention Mechanics and Materials Branch

Dear Sir:

I am enclosing five copies of the report covering the work done during the month of July, 1948, on "Fundamental Studies of Ceramic Materials". The report has been distributed as indicated by the distribution list bound with the report.

The research is continuing on the effect of varying the character of the pore structure on the properties of several burned alumina bodies. The rupture values obtained on specimens matured for 27 hours at 3100°F. did not vary appreciably, for a particular addition of filament, with the change in either the diameter of the filament or the type of alumina employed.

In the research on zircon bodies, the modulus of rupture values did not vary widely with change in grain size of the raw material or with change in forming method.

We shall be pleased to have any comments you or your associates or any person receiving these reports may care to make with regard to the research.

Sincerely,

Howard C. Cross.

Howard C. Cross

HCC:lkm
Enc. (5)

PROGRESS REPORT

on

FUNDAMENTAL STUDIES OF CERAMIC MATERIALS

to

OFFICE OF NAVAL RESEARCH, NAVY DEPARTMENT

CONTRACT NO. N5-ori-111, PROJECT ORDER NO. 1

by

J. F. Lynch, H. Z. Schofield, and C. R. Austin

BATTELLE MEMORIAL INSTITUTE

August 16, 1948

PROGRESS REPORT DISTRIBUTION LIST

"Fundamental Studies of Ceramic Materials"
Battelle Memorial Institute
Contract N5-ori-111

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TABLE OF CONTENTS

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SUMMARY

In the study of the effect of varying the character of the pore structure on the properties of alumina bodies, specimens were extruded from Norton Alundum 38900 and T-61 tabular alumina containing 2-1/2 or 5%, by volume, of organic filaments, 0.004 or 0.008 inch in diameter. When the specimens were matured for 27 hours at 3100°F., both the modulus of rupture and modulus of elasticity values for each alumina body decreased, as expected, with the progressive increase in porosity resulting from the burning out of the different amounts of the filaments. The rupture values did not vary appreciably, for a particular addition of filament, with the change in either the diameter of the filament or the type of alumina employed. The porosity was markedly higher and the modulus of elasticity lower for a specific tabular alumina structure than for the corresponding Norton Alundum structures.

Preliminary fabrication studies were made in the work on zircon bodies in which the raw material was prepared in two different degrees of fineness and was formed by dust pressing, plastic extrusion, and slip casting. When the specimens were matured at 3100°F., the modulus of rupture values did not vary widely with the change in grain size of the raw material nor with the change in forming method, although the bulk density values were higher and the apparent porosity was markedly lower for the specimens formed from the finer material. Examinations of the specimens and data indicated "overfiring" of the structure at this temperature of maturing.

EXPERIMENTAL WORK

(Data in Record Book No. 3658, pages 34 to 36, and Record Book No. 3804, pages 29 to 85. Work conducted during the period from July 1 to July 31, 1948.)

Alumina Bodies

Effect of Pore-Character Variations

Specimens were formed by plastic extrusion* from bodies of two aluminas, Norton Alundum 38900 and T-61 tabular alumina**, each containing

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* The forming technique is described in the Appendix.

** The average grain sizes of these materials, as usually supplied, were approximately 5 and 22 microns, respectively.

separate additions of two sizes of Nylon monofilaments. The specimens were fired for 27 hours at 3100°F. The properties are given in Table 18 of the Appendix.

As expected, both the modulus of rupture and modulus of elasticity values for each alumina body decreased with the progressive increase in porosity resulting from the burning out of the different amounts of the monofilaments. The rupture values did not vary appreciably, for a particular addition of monofilaments, with the change in either the diameter of monofilament or the type of alumina employed. The porosity was significantly higher and the modulus of elasticity value lower for a specific T-61 tabular alumina structure than for the corresponding Norton Alundum structure.

Although the fabrication techniques employed in this work were much improved over those reported last month*, the present investigation is still considered preliminary in nature.

Zircon Bodies

Preliminary fabrication and burning treatments were conducted to aid in selecting techniques for use in a detailed study of zircon bodies. The raw material employed was TAM Granular Zircon, wet-milled in one-gallon mills of a zircon-porcelain type for 12 and 48 hours. Specimens

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* Report dated July 16, 1948.

were formed by dust pressing, plastic extrusion, and by slip casting, and were matured for 3 hours at 3100°F.* The properties of the specimens are given in Table 19 of the Appendix.

The modulus of rupture values for these preliminary specimens, when matured at this temperature, did not vary widely with the change in grain size of the raw material or with the change in method of forming. However, the linear shrinkage and bulk density were markedly higher for the specimens of the material which was milled for 48 hours than for those of the material milled for 12 hours, and the apparent porosity values of the former specimens were very low.

A cursory petrographic examination indicated significant dissociation of the zircon in these matured specimens. Also, a comparison of the apparent porosity values with the respective bulk density values indicated a relatively high proportion of sealed pores.

FUTURE WORK

Work will be continued on the investigation of the effect of varying the pore character on the properties of alumina specimens.

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* The preparation of the bodies and the methods of forming were essentially the same as were described for alumina bodies in the Appendix of the report dated March 16, 1948. The techniques of firing were similar to those described for specimens of alumina in the Appendix of the report dated December 16, 1947. The details for these procedures will be given in a later report when developed further for the zircon bodies.

Techniques will be developed for fabricating body structures having various amounts and shapes of pores.

The study of zircon bodies will be continued in further investigations of the preparation of a raw material in various grain sizes and with high purity. An appropriate fabrication and maturing program will be developed for the detailed study of this type of body.

JFL:HZS:CRA/lkm
September 3, 1948

APPENDIX

APPENDIX

Preparation and Forming of Alumina Bodies

The alumina and Nylon monofilaments of the batch were mixed together by hand and then were placed in a muller-type, Lancaster mixer of laboratory size: a 5% addition of Mogul gum was added continuously during the first few minutes of mixing. Mixing then was continued for an additional 15 minutes. A mixture consisting of a 10% addition of water, a 5% addition of glycerin, and a 0.2% addition of phenol was prepared and added slowly to the mixing dry batch. Additional water then was added, as necessary, to attain the proper extrusion consistency. The total water additions ranged from 10% for the body of tabular alumina containing no Nylon monofilaments to 18-1/2% for the body of Norton Alundum containing the higher amount of monofilaments, 0.004 inch in diameter.

The plasticized bodies were extruded continuously through the steel orifice, 5/16" x 5/16", of a piston-type, extrusion apparatus. The cylinder of the apparatus was "deaired" to an absolute pressure of approximately 25 millimeters of mercury.

TABLE 18. PROPERTIES OF POROUS ALUMINA BODIES

Nylon Monofilament Addition, % by Volume		Properties of Matured Specimens				
Monofilaments, 0.004 Inch in Diameter*	Monofilaments, 0.008 Inch in Diameter*	Linear Shrinkage, %	Bulk Density, g./cc.	Apparent Porosity, %	Modulus of Rupture, Lbs. per Sq.In.	Modulus of Elasticity, 10^6 Lbs. per Sq.In.**
				(Norton Alundum 38900)		
2.5	—	11.6	3.61	6.5	18,300	53.5
5.0	—	11.7	3.53	9.0	13,300	46.5
—	2.5	11.4	3.69	3.4	17,900	54.0
—	5.0	11.6	3.55	7.9	14,700	48.8
—	—	11.2	3.75	1.8	29,200	60.5
				(T-61 Tabular Alumina)		
2.5	—	8.2	3.21	19.6	18,400	38.8
5.0	—	8.5	3.17	20.7	14,300	37.5
—	2.5	8.2	3.24	18.9	17,700	39.0
—	5.0	8.2	3.19	20.2	14,500	39.0
—	—	7.9	3.38	15.0	24,200	44.2

Note: Specimens, 5/16" x 5/16" x 3", were formed by plastic extrusion and were matured for 27 hours at 3100°F. Values given are averages based on the results from at least 4 individual specimens, except each value for modulus of elasticity which is for one specimen only.

* Approximate length of each monofilament was 1/4 inch.

** Values were obtained from the calculated unit stress and the measured unit deflection when the specimens were tested in flexure, on a 2-inch span, with a concentrated load at midspan. Deflections were measured at midspan on the tension side of each specimen by using an SR-4 Strain Gage, Type A-12, supplied by the Baldwin Locomotive Works, Philadelphia, Pennsylvania. Values given were averages for the ranges approximately to rupture.

TABLE 19. PROPERTIES OF BURNED SPECIMENS OF ZIRCON

Type of Zircon	Method of Preparation	Method of Forming	Linear Shrinkage, %	Bulk Density, g./cc.	Apparent Porosity, %	Modulus of Rupture, Lbs./Sq.In.
TAM Zircon Granular	Ground for 12 hours in ball mill of zircon-porcelain type	Dust pressing	4.7	3.31	18.8	10,700
		Plastic extrusion	5.9	3.29	19.0	12,600
		Slip casting	7.8	3.00	26.5	8,900
Ditto	Ground for 48 hours in ball mill of zircon-porcelain type	Dust pressing	10.9	3.52	0.1	11,500
		Plastic extrusion	10.5	3.54	0.1	12,800
		Slip casting	16.4	3.50	0.2	13,100

Note: Specimens, 5/16" x 5/16" x 3", were matured for 3 hours at 3100°F. Values given are averages of the results obtained from at least 4 individual specimens.